S
333.92
N7wrl
1979

RENEWABLE ENERGY REPORT LIBRARY

STATE DOCUMENTS COLLECTION

FEB 21 1984

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

PLEASE RETURN

WIND RESOURCE ASSESMENT: LIVINGSTON-SPRINGDALE AREA

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

MONTANA STATE LIBRARY
S 333.92 N7wrL 1979 c.1 Brelsford
Wind resource assess[s]ment: Livingston-S
3 0864 00047327 5

WIND RESOURCE ASSESMENT: LIVINGSTON-SPRINGDALE AREA

Prepared by

Don Brelsford
Brelsford Engineering
P.O. Box 1252
Bozeman, MT 59715

August, 1979

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number 212-781

Available from

Montana State Library, 1515 East Sixth Avenue
Justice and State Library Building, Helena, Montana 59620

This report was prepared under an agreement funded by the Montana Department of Natural Resources and Conservation. Neither the Department, nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information apparatus, product, or process disclosed, or represents that its use would not infringe on privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the Department of Natural Resources and Conservation or any employee thereof. The reviews and opinion of authors expressed herein do not necessarily state or reflect those of the Department or any employee thereof.

CONTENTS

Introduction	1
Wind Energy Survey Area	2
Comparative Meteorological Parameter	5
Wind Data Reduction	6
Correlational Analysis	8
Available Wind Power Forecast	9
Potential Wind Energy Forecast	11
Appendix A	A
Appendix B	B
Appendix C	C

LIST OF FIGURES

USGS Topographical Maps

		Page
1.	Livingston-Springdale Wind Energy Survey Area	12
2.	LIV-WES Sites Near Livingston	13
3.	FAA-FSS Data Station and Nearby LIV-WES Sites	14
4.	Brittan Ranch - S3C	15
5.	Koffee Kup Ranch - S1B	16
6.	Hunter's Hot Springs - S1C	17

LIST OF TABLES

		Page
1.	S1A Harvatt's Flat, December 1978	18
2.	S1A Harvatt's Flat, Dec. 1978, Jan.-Feb. 1979	19
3.	S1B Koffee Kup Ranch, Jan. Feb. 1979	20
4.	S1C Hunters Hot Springs, Jan. Feb. 1979	21
5.	Summary of Results - Series 1	22
6.	S2A Park County Landfill, Mar. Apr. 1979	23
7.	S2B Meyers Ranch, Mar. Apr. 1979	24
8.	S2C Hillman Ranch, Apr. May 1979	25
9.	Summary of Results - Series 2	26
10.	S3A Livingston West, May, June, July 1979	27
11.	S3B McGuire Hill, June 1979	28
12.	S3C Brittan Ranch, May, June, July 1979	29
13.	Summary of Results - Series 3	30
14.	Mission Field FAA-FSS Wind Speed - Series 1	31
15.	Mission Field FAA-FSS Wind Speed - Series 2	32
16.	Mission Field FAA-FSS Wind Speed - Series 3	33
17.	Wind Speed Correlation Factors - Series 1	34
18.	Wind Speed Correlation Factors - Series 2	35
19.	Wind Speed Correlation Factors - Series 3	36
20.	Mission Field 19721976 Annual Wind Speed by Month	37
21.	Wind Speed Forecast - Series 1 Sites	38
22.	Wind Speed Forecast - Series 2 Sites	39
23.	Wind Speed Forecast - Series 3 Sites	40
24.	Available Wind Power Forecast - Series 1 Sites	41
25.	Available Wind Power Forecasts - Series 2 Sites	42
26.	Available Wind Power Forecasts - Series 3 Sites	43
27.	Potential Wind Energy Forecast - Series 1 Sites	44
28.	Potential Wind Energy Forecast - Series 2 Sites	45
29.	Potential Wind Energy Forecast - Series 3 Sites	46

INTRODUCTION

Two percent of the solar energy reaching the earth is available in the form of wind energy. Surface winds over the United States, available for energy conversion, are sufficient to supply 30 times the present total energy consumption of the U.S. During Fall and Winter seasons, Livingston and the upper Yellowstone River Valley experience over three times the available wind power of other Montana areas.

The Brelsford Engineering wind energy survey of the Livingston-Springdale, MT area was a research project funded under the Alternative Renewable Energy Sources Program of the Montana Department of Natural Resources and Conservation. This wind energy survey project represents a beginning in the technical determination of the available wind energy resource in Southwestern Montana. The nine sites surveyed were topographically appropriate and located near potential farm, ranch, public and commercial wind energy users. A wide variety of small wind energy conversion systems are commercially and economically available from private industry. They are beginning to be put to use, privately and publically, to recover the reliable, renewable energy in the wind.

WIND ENERGY SURVEY AREA

Nine Livingston wind energy survey (LIV-WES) sites were instrumented for wind measurements during this three phase, one-year project. The Series 1 phase covered the months of December 1978, January and February 1979; Series 2 was in March, April, and May, 1979; Series 3 was May, June and July 1979.

At each site, a 10m (32.8 ft.) telescopic mast was vertically erected and adequately instrumented and equipped for continuous wind speed and direction measurement and recording. The wind measurement and recording systems were purchased from Natural Power, Inc., New Boston, New Hampshire. These NPI systems were battery powered to allow for remote, continuous 24 hr/day operation. The recording systems were contained in weather proof boxes for reliable, all-weather operations. Descriptions and specifications of the NPI systems will be found in Appendix C.

The three LIV-WES sites for Series 1 were located near the outer boundaries of the Livingston-Springdale study area.

S1A - Harvatt's Flat - 2 miles south of Livingston, south of I-90, on the eastern bench above the Yellowstone River, 6 miles west of Livingston Municipal Airport, Mission Field.

S1B - Koffee Kup Ranch - 10 miles northeast of Livingston on hilltop one mile east of Shields River, 5 miles north of the Yellowstone River Valley.

S1C - Hunter's Hot Springs - 3 miles northeast of Springdale, 16 miles east of Livingston, 2 miles north of Yellowstone River, on hilltop west of the Hot Springs.

The three sites for Series 2 were located as follows:

S2A - Park County Landfill - 4 miles east of Livingston, south of I-90, on the bench above Chicken Creek and the Yellowstone River Valley, 2 miles west of Mission Field.

S2B - George Meyers Ranch - one mile southeast of Livingston, north of I-90, on the north shoulder of Harvatt's Flat, adjacent to the abandoned Livingston Airport.

S2C - Charles Hillman Ranch - six miles northeast of Livingston, on the west side of the Shields River Valley as it enters the Yellowstone River Valley, west of U.S. 89.

The three sites for Series 3 were located as follows:

S3A - Livingston West - 2 miles west of Livingston, north of I-90, south of U.S. 10, on a hill above the Leonard Adam's home.

S3B - McGuire Hill - one-half mile northeast of Livingston, one-quarter mile north of residential area, on the abandoned police radio tower hill.

S3C - Gordon Brittan Ranch - 9 miles west of Livingston, one and one half miles south of the Yellowstone River, on the east bench above Mission Creek and the Brittan Ranch home.

The location of the nine LIV-WES sites and the FAA-FSS wind data station at the Livingston Municipal Airport-Mission Field are shown in Figure 1. The four sites that were located at appropriate topographic sites near Livingston were; S1A, S2B, S3A and S3B (See Figure 2). The similarity of terrain between the FAA-FSS wind data station at the Livingston Airport and the County Landfill Site - S2A is indicated in Figure 3. Brittan Ranch - S3C site location above Mission Creek and about three miles east of the airport, is shown in Figure 4. From the topographical map on Figure 5 it may be seen that the topography for the Koffee Kup Ranch - S1B site was positive. The fact that this site was 6 miles north of the Yellowstone River Valley apparently had a direct negative effect on the of available wind power and potential wind energy at the S1B site. Hunter's Hot Springs site - S1C on a moderate hill in the small Hunter's Creek valley on the northside of the Yellowstone River Valley as it opens to the Northern Great Plains apparently

provides the positive ground effects that result in the relatively high available wind power and potential wind energy that has been determined at site S1C.

Topographically and climatologically Livingston is located at the top of the Yellowstone River "wind shed." The strongest winds occur in the Winter season when the high pressure, relatively warm air masses from the Southwest U.S. flow over Western Montana into the low pressure zones of the Northern Great Plains cause by cold Arctic air. At Livingston, high pressure "chinook" winds commonly reach the ground in the inhabited rural areas of the Yellowstone River Valley and neighboring foothills. As a direct consequence, substantial potential wind energy is available for conversion and use, in the populated Livingston-Springdale area, particularly during the cold Winter season when thermal energy for space heating is in high demand.

COMPARATIVE METEOROLOGICAL PARAMETER

"Available Wind Power" is a useful meteorological parameter for the comparative analysis of candidate wind energy conversion system sites. On this project it was used as a comparative meteorological parameter for the wind energy characterization and analysis of the nine LIV-WES sites and for the Livingston-Springdale area in general.

Available wind power is a function of the kinetic energy per unit mass of air and consequently is proportional to the volume and density of the moving air. Available wind power per unit area (P/A) is proportional to the air density multiplied by the wind speed cubed, $(W_s)^3$.

At the normal Montana atmospheric pressure of 12 psia:

$P/A = 0.04467 \times W_s^3$, - in units of watts/$m^2$ when W_s is in mph.

$P/A = 0.06820 \times W_s^3$, - in units of watts/$m^2$ when W_s is in knots.

Calculation of Available Wind Power requires use of the percentage frequency distribution of wind speed rather than simply the average wind speed. If the wind speed is a steady 15 mph, 150 watts/m^2 would be the Available Power. If it moves 10 mph half the time and 20 mph half the time, again averaging 15 mph, Available Wind Power would be 200 watts/m^2, which is 33% higher because of the cubic relationship of Available Power to wind speed.

WIND DATA REDUCTION

The LIV-WES wind speed and direction measurement and recording systems were purchased from Natural Power, Inc., New Boston, New Hampshire. Three complete 10m (32.8 ft) systems were installed at three individual sites in each of the three series of the project. In this way the nine sites were surveyed for wind data for up to three months each. The wind data was continuously recorded 24 hr/day on strip paper chart Rustrack Recorders built into the NPI wind measurement and recording systems. In carrying out data reduction, hourly wind speed (W_s) and wind direction (W_d) data points were read visually and recorded manually in matrix format. The matrix format was designed to provide properly arranged data for the calculation of percentage frequency distribution of W_s and W_d for each month and for the overall survey period of the particular site.

The percentage frequency distribution of wind speed and wind direction for S1A in December 1978 is in Table 1. In Table 2 is the average percentage frequency distribution of wind speed at S1A for the appropriate Series 1 period. Directly comparable data for S1B is on Table 3, and for S1C on Table 4. This data indicates the percent of time when the wind speed was measured to be within the indicated wind speed classes and directions. The mean wind speed is the weighted average wind speed for the time period. The Available Power is calculated, as previously described, based upon the percentage frequency of time the wind speed was in the various speed classes and not on the mean wind speed.

Summary of results of the wind energy survey for LIV-WES Series 1 is on Table 5. For Series 2, the wind survey results for the corresponding sites will be found as follows: S2A, Table 6; S2B, Table 7; and S2C, Table 8. Summary of results for Series 2 will be found on Table 9. Series 3 wind survey results will be found as follows: S3A, Table 10; S3B, Table 11; and S3C, Table 12. On Table 13 will be found the summary of results for Series 3. The shortened period of two months on five of the six sites of Series 1 and 2 was the direct result of instrument recording equipment damage and repair time requirements. At S3B site the shortened, three weeks period resulted from severe, destruction vandalism by unknown persons.

The period of time for wind measurements and recording and the quantity of hourly data points that were derived for each of the nine LIV-WES sites are as follows:

Site	Period	Days	Hourly Data
S1A	11/28/78 - 2/27/79	91	2184
S1B	1/4/79 - 3/8/79	63	1512
S1C	12/21/78 - 3/6/79	75	1800
S2A	3/6/79 - 5/1/79	55	1320
S2B	3/8/79 - 5/10/79	63	1512
S2C	4/17/79 - 6/1/79	44	1056
S3A	5/3/79 - 8/1/79	90	2160
S3B	6/1/79 - 7/2/79	31	744
S3C	5/10/79 - 8/2/79	83	1992

CORRELATION ANALYSIS

The relatively new Livingston Municipal Airport, Mission Field, was constructed and put into operation about 1960. At Mission Field, the FAA Flight Service Station (FAA-FSS) measures and records weather and meteorological data for aeronautical purposes. At the present time, FAA-FSS operates on a 16 hr/day basis. Previous to 1977 this station recorded wind speed and direction data hourly on a 24 hr/day basis. Consequently, BE selected the five year period from January 1972 through December 1976 to be the long term wind data base for the LIV-WES wind energy forecasts. In Table 14 is a comparative summary of the FAA-FSS wind speed and available power determinations for the Series 1 period, and the selected five year period, 1972 through 1976. (Detailed FAA-FSS wind data will be found in Appendix A). Comparable data for Series 2 is in Table 15, and for Series 3 in Table 16.

The procedure for developing long-term wind forecasts was derived from a recent Battelle Pacific Northwest Laboratories report.* Battelle Pacific Northwest Laboratories currently provides management support to the Wind Characteristic Program Element of the Federal Wind Energy Program under contract to the U.S. Department of Energy.

In order to develope the site specific LIV-WES to FAA-FSS Correlation Factor (CF), the mean wind speed, W_s, for the particular LIV-WES site, over the appropriate time period, was divided by the directly comparable mean wind speed derived from FAA-FSS wind data for the same period of time. Wind speed Correlation Factors for Series 1 are in Table 17, for Series 2 in Table 18, and for Series 3 in Table 19. For comparison purposes only LIV-WES and FAA-FSS wind speed data are given in both mph and knots (1.0 knot = 1.15 mhp).

* "A Siting Handbook for Small Wind Energy Conversion Systems", H.L. Wegley, et al., Battelle PNL #2521, May 1978.

AVAILABLE WIND POWER FORECAST

Mean annual FAA-FSS Mission Field wind speed frequency distribution, by months of the year, for the five year period from January 1972 through December 1976, is provided in Table 20. This FAA-FSS wind data was used as the basis for the long-term forecasts of Available Wind Power and Potential Wind Energy for each of the nine LIV-WES sites.

To accomplish site-specific, long-term wind forecasts, the midpoint of each of the speed ranges for each of the columns from Table 20 was multiplied by the appropriate, site-specific Correlation Factor. In this way the long-term matrix of percentage frequency distribution of wind speed by month of the year was determined for each LIV-WES site. The summary of long-term wind speed forecasts for Series 1 sites are in Table 21, for Series 2 sites in Table 22, and for Series 3 in Table 23. Detailed long-term forecasts of percentage frequency of wind speed by month for each of the nine LIV-WES sites will be found in Appendix B.

It may be recalled that Available Wind Power is proportional to wind speed cubed (W_s^3). The long-term wind speed percentage frequency distribution forecasts was used to calculate the long-term monthly and annual Available Wind Power forecasts for each particular LIV-WES site (See Tables 24, 25 & 26).

Using the previously discussed comparative meteorological parameter, Available Wind Power, as the basis of comparative analysis of each of the nine LIV-WES sites on a long-term yields the following results:

Site	Available Power Mean Annual (watts/m^2)	Comparison Percentage	Comparison Rank
FSS	310.8	100.0	--
S1A	277.6	89.3	5
S1B	91.4	29.4	9
S1C	286.8	92.3	4
S2A	414.4	133.3	1
S2B	159.1	51.2	8
S2C	251.2	80.8	7
S3A	251.7	80.1	6
S3B	360.6	116.0	2
S3C	288.9	93.0	3

POTENTIAL WIND ENERGY FORECAST

Energy is equal to power multiplied by the time period of application of the power. Theoretical aerodynamic limitations on wind energy conversion systems (WECS) indicate that 16/27th or about 60% of the total wind energy in the moving air mass may be recoverable as "Potential Wind Energy." Commercially available WECSs are able to provide up to fifty percent conversion of total wind energy into various useable energy forms, such as electricity, compressed air, etc. Potential Wind Energy forecasts which represent 16/27th of the total available wind power multiplied by the appropriate time period have been calculated, and for LIV-WES Series 1 sites are in Table 27, for Series 2 in Table 28, and for Series 3 in Table 29.

Comparative analysis of each LIV-WES Series 1, 2 and 3 sites is shown below. It can be seen that the Potential Wind Energy that is theoretically recoverable by wind energy conversion systems is in the range of 80 to 200 kwhr/ft^2 in the Livingston-Springdale area of Montana.

Site	Mean Annual Potential Wind Energy (kwhr/m^2)	(kwhr/ft^2)
FSS	1612.9	149.9
S1A	1440.8	133.9
S1B	474.5	44.1
S1C	1489.2	138.4
S2A	2150.9	199.9
S2B	826.4	76.8
S2C	1304.1	121.2
S3A	1303.0	121.1
S3B	1866.8	173.5
S3C	1495.6	139.0

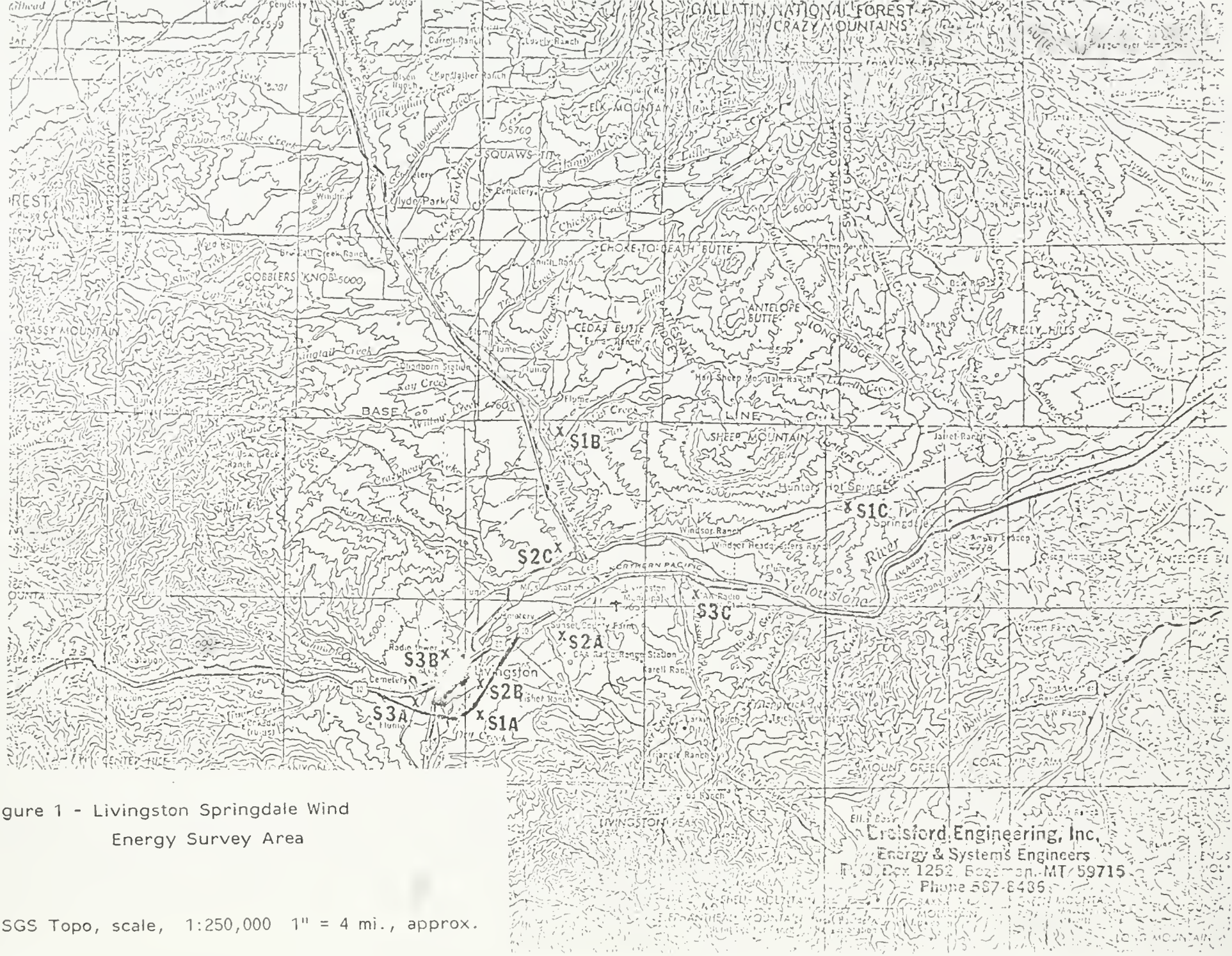
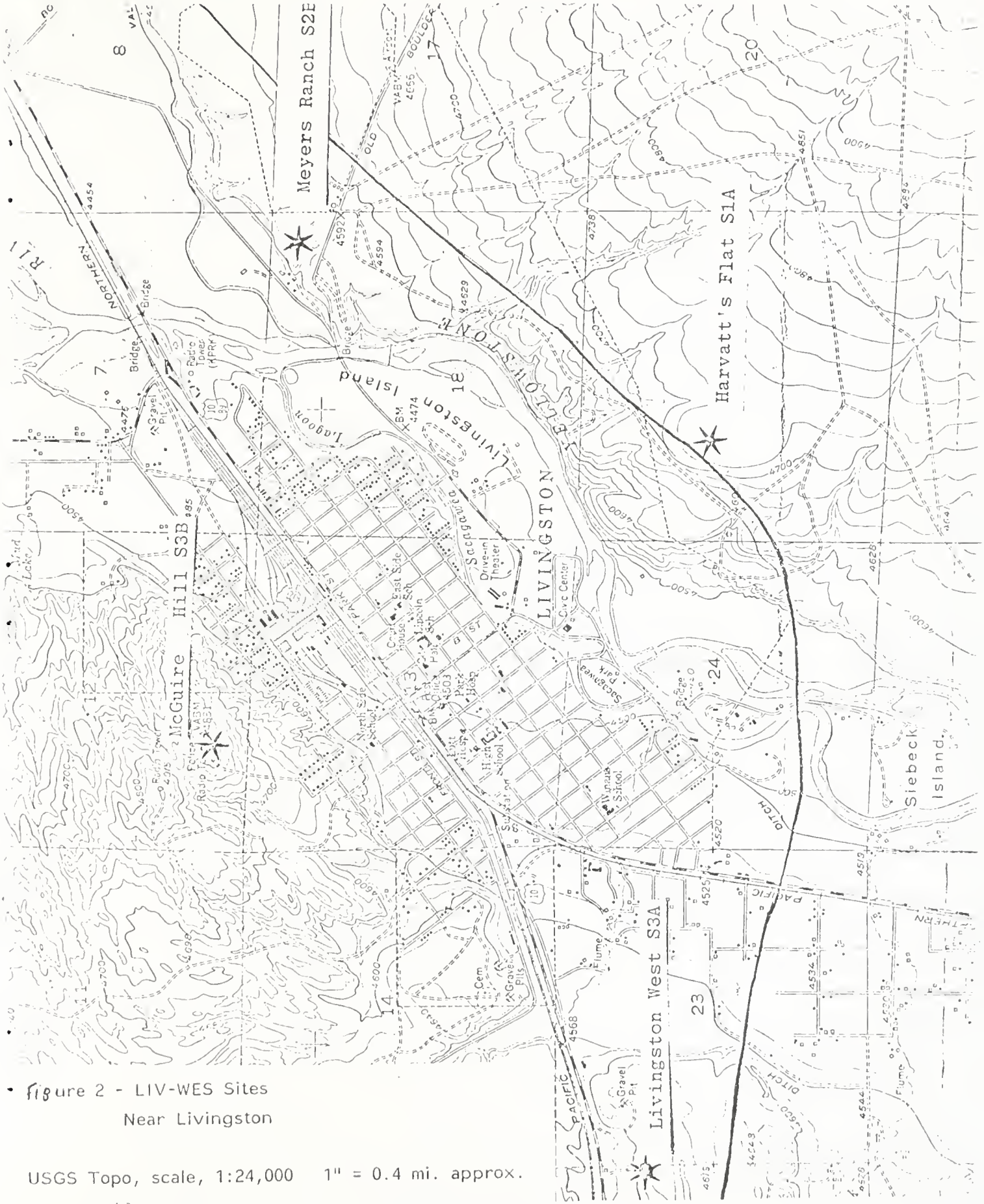


Figure 1 - Livingston Springdale Wind Energy Survey Area

USGS Topo, scale, 1:250,000 1" = 4 mi., approx.


Meyers Ranch S2E
Harvatt's Flat S1A
Livingston Island
LIVINGSTON
McGuire Hill S3B
Livingston West S3A
Siebeck Island
Sacagawea Park
Civic Center
Drive-in Theater
Lagoon
Gravel Pit
Radio Tower
Bridge
Cemetery
Flume
DITCH
PACIFIC
NORTHERN
Lincoln School
Lincoln Park
Park Lodge
Court House
East Side School
North Side School
Junior High School
Sacagawea Park
Radio Tower (KPRK)
Radio Tower (KGVS)
Radio Tower (KGLN)
Gravel Pits
Cem
Lake
Bridge
Bridge
Bridge

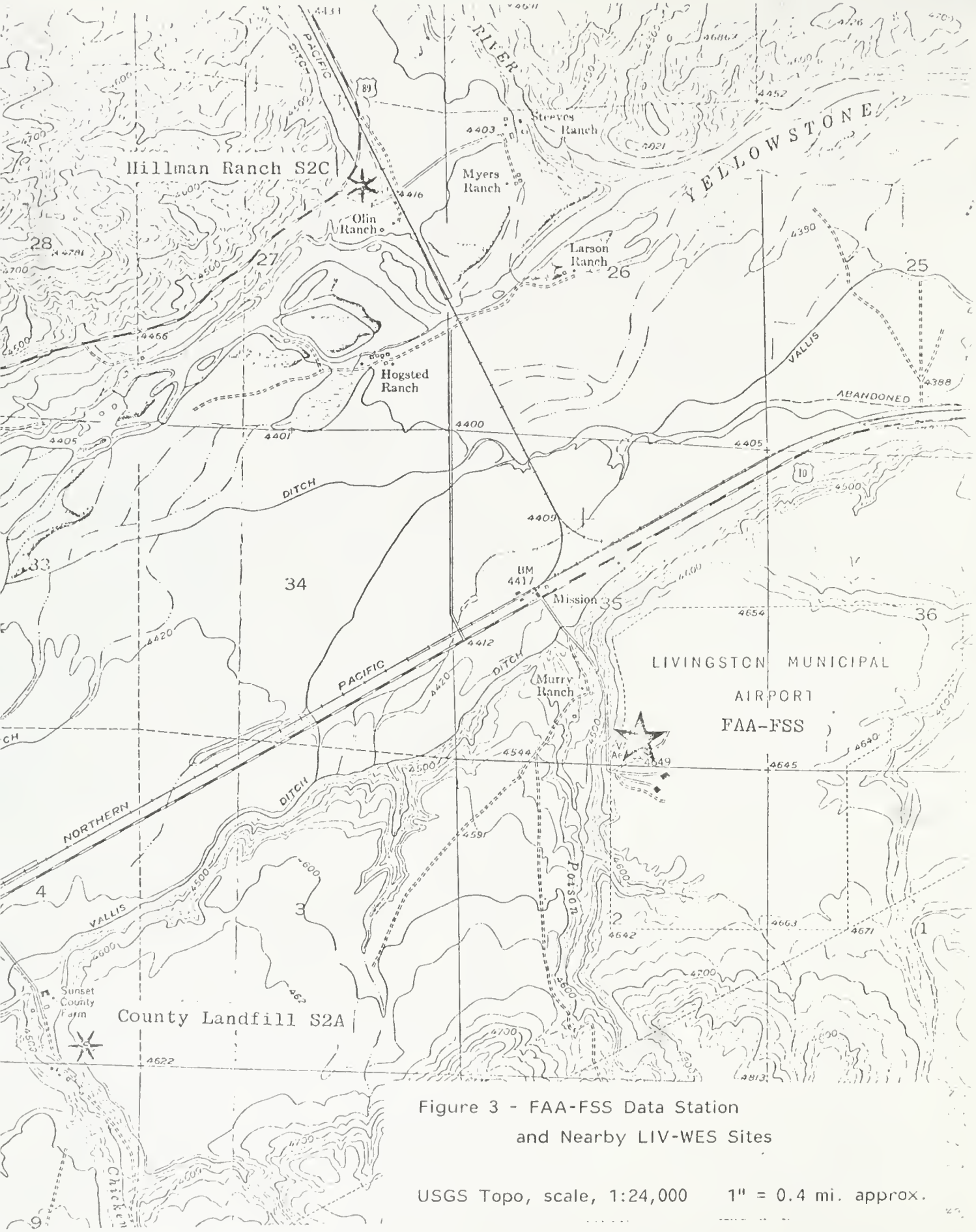


Figure 3 - FAA-FSS Data Station and Nearby LIV-WES Sites

USGS Topo, scale, 1:24,000 1" = 0.4 mi. approx.

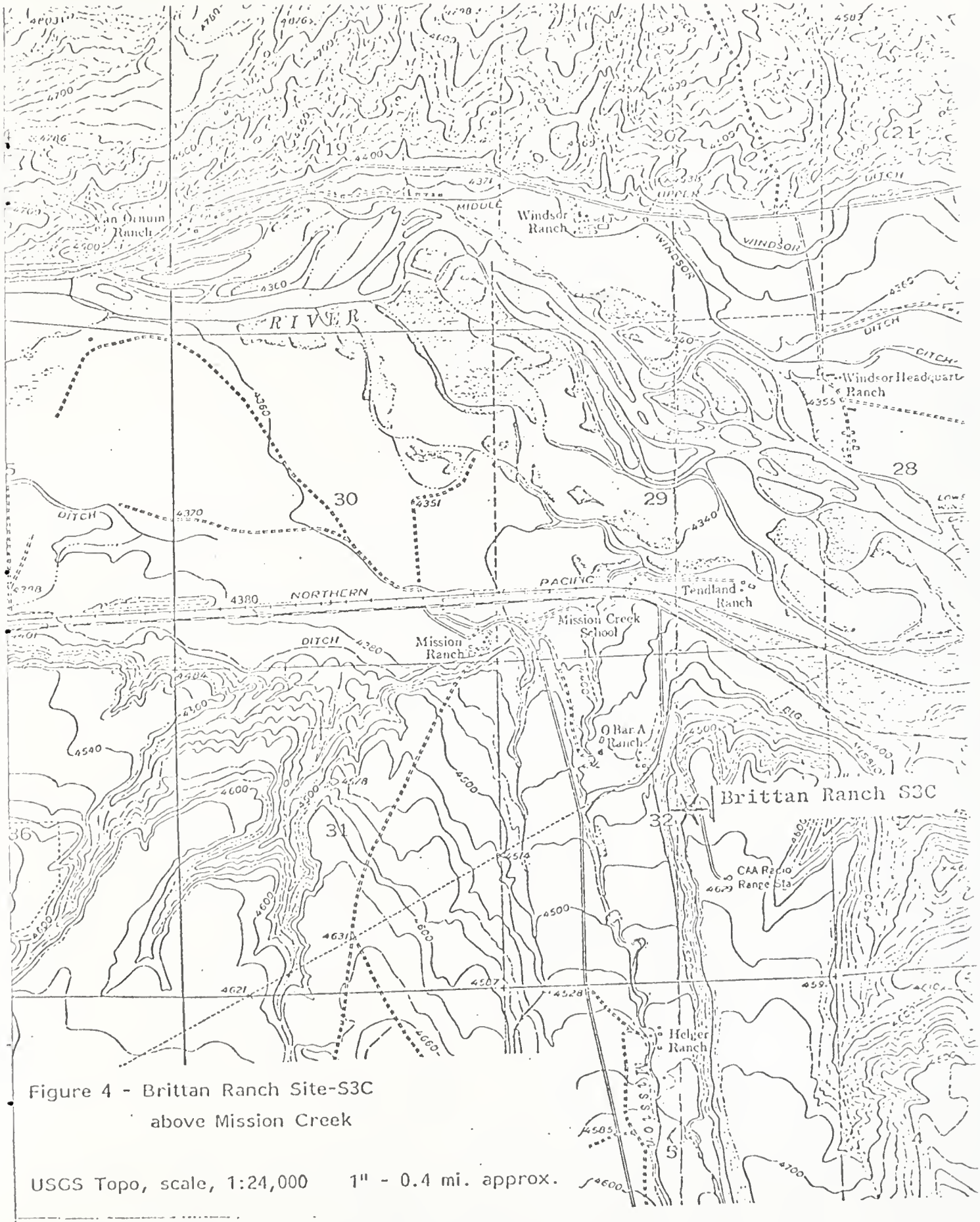


Figure 4 - Brittan Ranch Site-S3C
above Mission Creek

USGS Topo, scale, 1:24,000 1" - 0.4 mi. approx.

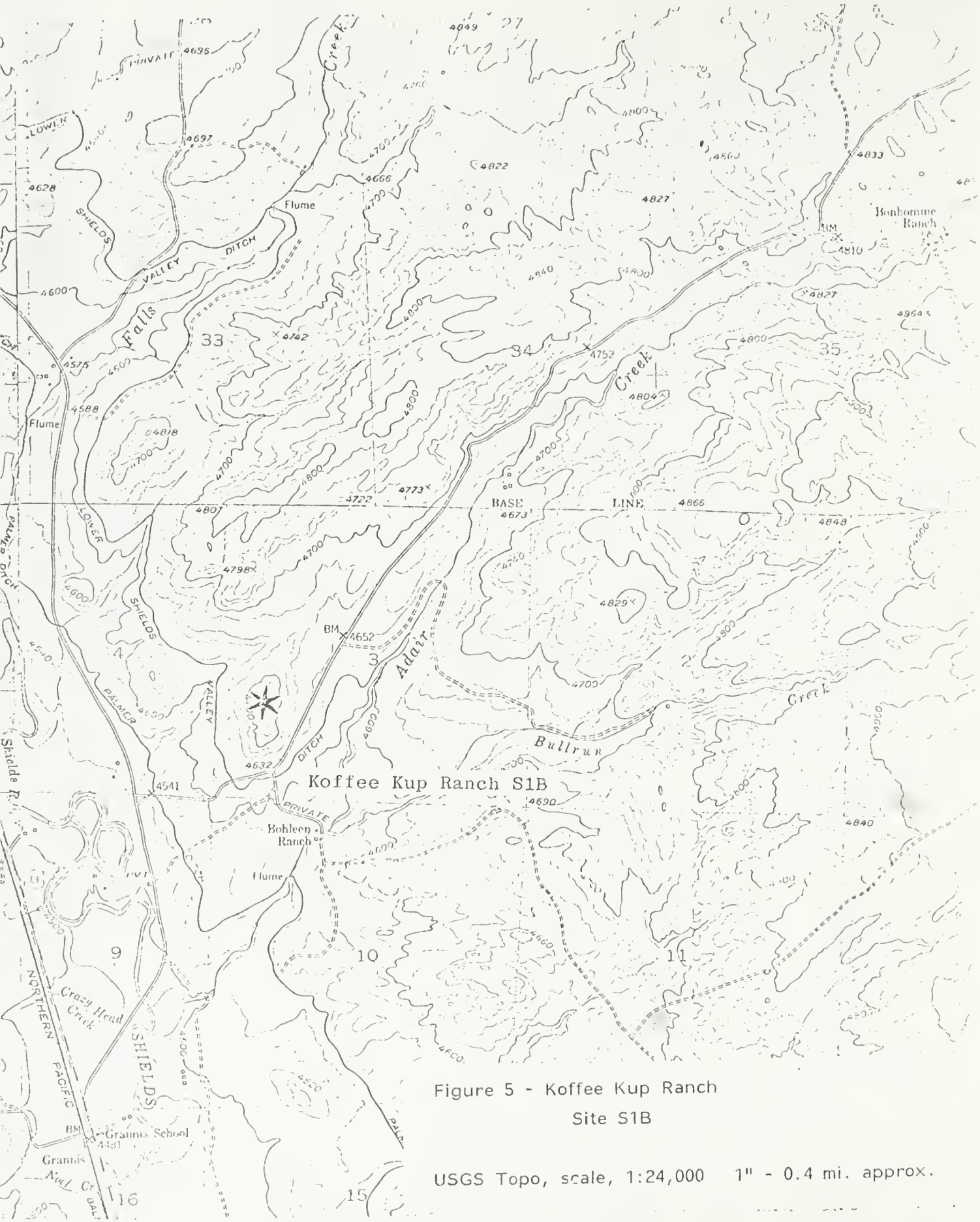


Figure 5 - Koffee Kup Ranch
Site S1B

USGS Topo, scale, 1:24,000 1" - 0.4 mi. approx.

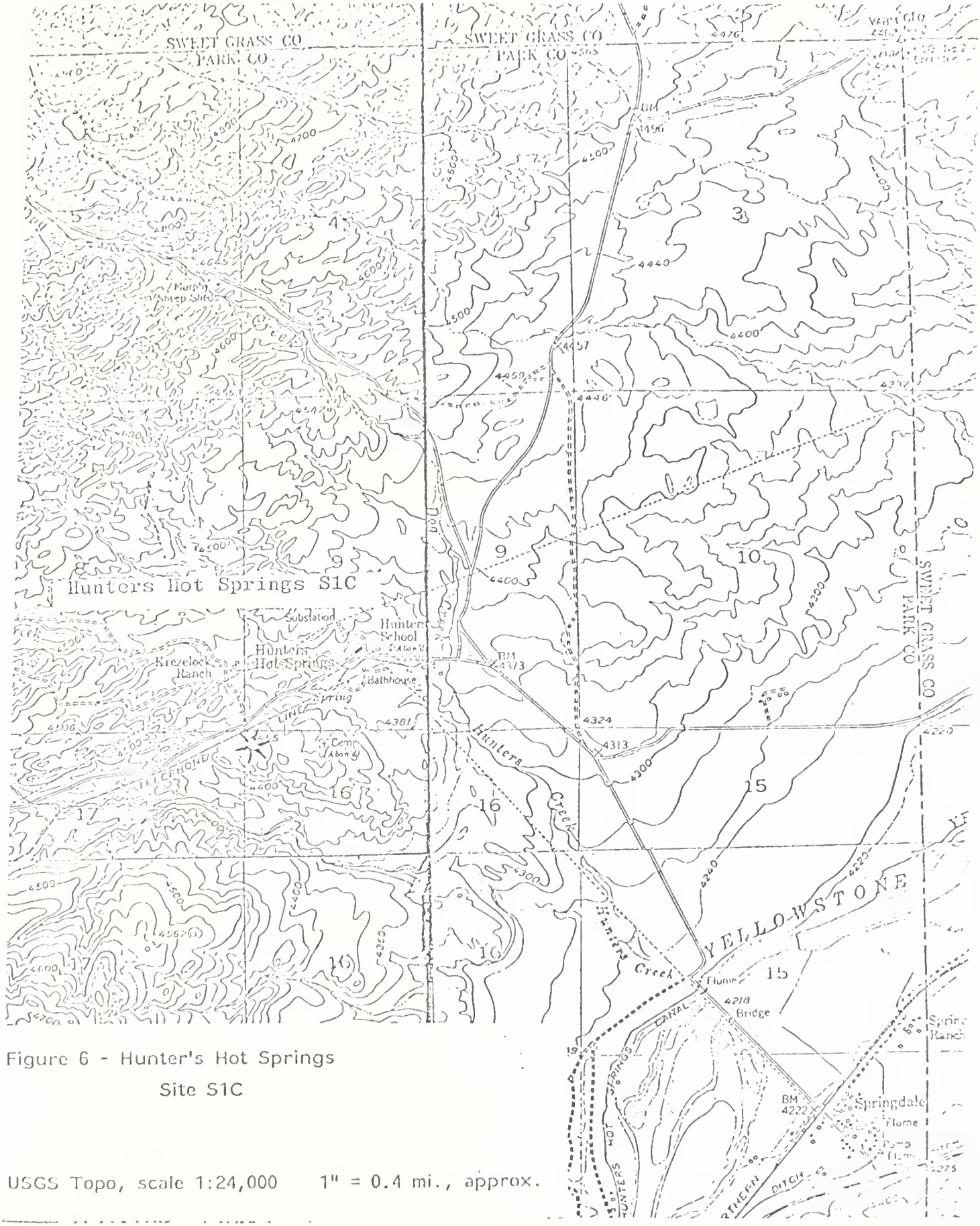


Figure 6 - Hunter's Hot Springs
Site S1C

USGS Topo, scale 1:24,000 1" = 0.4 mi., approx.

Table 1

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston WES - Series 1 | S1A - Harvatt's Flat | December 1978

Direction	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
N	0.8	--	--	--	0.8	--	0.8	2.5	18.2	666.0
NE	0.8	--	1.7	--	--	--	--	2.5	7.8	35.3
E	0.8	0.8	0.8	2.5	--	--	--	5.0	11.0	101.4
SE	0.8	3.3	0.8	0.8	--	--	--	5.8	7.3	37.9
S	2.5	0.8	--	--	1.7	--	--	5.0	9.4	163.4
SW	0.8	2.5	0.8	2.5	3.3	5.8	25.6	41.3	27.8	1191.0
W	1.7	2.5	4.1	5.0	7.4	--	5.0	25.6	18.3	496.0
NW	0.8	0.8	3.3	3.3	--	4.1	--	12.4	17.0	405.0
Percent	9.1	10.7	11.6	14.0	13.2	9.9	31.4	100.0		

December Mean Wind Speed, W_s = 17.7 knots, 20.4 mph

December Mean Available Power, Wm^{-2} = 701.9 watts/m^2

Table 2

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 1 S1A - Harvat's Flat December 1978, January, February 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
Dec.	9.1	10.7	11.6	14.0	13.2	9.9	13.1	100.0	20.4	701.9
Jan.	21.6	16.8	14.4	18.4	12.0	5.6	11.2	100.0	13.8	337.6
Feb.	13.6	11.7	14.6	7.8	9.7	11.7	31.1	100.0	19.5	689.4
Dec., Jan., Feb.	14.8	13.1	13.5	13.4	11.6	9.1	24.6	100.0	17.9	577.0

Table 3

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 1 S1B - Koffee Kup Ranch January, February 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
Jan.	34.3	32.4	16.7	9.8	2.9	3.9	--	100.0	7.7	83.9
Feb.	16.3	21.5	17.1	11.0	8.5	19.1	6.5	100.0	14.6	373.4
Jan.- Feb.	25.3	27.0	16.9	10.4	5.7	11.5	3.3	100.0	11.2	228.7

Table 4

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 1 | S1C - Hunters Hot Springs | January, February 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
Jan.	18.4	7.9	15.8	13.2	16.7	20.2	7.9	100.0	16.7	448.3
Feb.	13.0	11.4	18.5	15.6	16.1	14.0	11.4	100.0	16.7	443.6
Jan.-Feb.	15.7	9.65	17.2	14.4	16.4	17.1	9.7	100.0	16.7	445.9

Table 5

LIVINGSTON WIND ENERGY SURVEY - SERIES 1
SUMMARY OF RESULTS
December 1978 - February 1979

Site	Month	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watts/m^{-2})
S1A Harvatt's Flat				
	Dec. '78	20.4	17.7	701.9
	Jan. '79	13.8	12.0	337.6
	Feb. '79	19.5	17.0	689.4
	Jan.-Feb.	16.7	19.2	514.5
	Dec.-Feb.	17.9	15.6	577.0
S1B Koffee Kup Ranch				
	Jan. '79	7.7	6.7	83.9
	Feb. '79	14.6	12.7	373.4
	Jan.-Feb.	11.2	9.7	228.7
S1C Hunters Hot Springs				
	Jan. '79	16.7	14.5	448.3
	Feb. '79	16.7	14.5	443.6
	Jan.-Feb.	16.7	14.5	445.9

Table 6

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 2 S2A - Park County Landfill March, April 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
Mar.	7.7	17.9	27.6	16.8	11.5	10.7	7.6	100.0	14.9	334.1
Apr.	4.7	20.8	21.4	16.4	15.6	13.7	7.3	100.0	16.0	376.2
Mar.-Apr.	6.2	19.4	24.5	16.6	13.6	12.2	7.5	100.0	15.5	356.2

Table 7

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 2 S2B - Meyer Ranch March, April 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
Mar.	17.8	25.4	28.8	14.4	7.3	5.0	1.3	100.0	10.7	151.0
Apr.	5.4	26.4	30.4	22.5	9.5	4.7	1.0	100.0	12.2	169.3
Mar.-Apr.	11.6	25.9	29.6	18.4	8.4	4.9	1.2	100.0	11.5	161.4

Table 8

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 2 S2C - Hillman Ranch April, May 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
Apr.	1.4	17.8	40.7	24.9	13.	2.3	--	100.0	12.9	153.9
May.	0.9	30.0	31.4	18.0	14.8	4.0	0.5	100.0	12.6	171.9
Apr.-May	1.2	23.9	36.1	21.5	13.9	3.2	0.3	100.0	12.7	164.3

Table 9

SUMMARY OF RESULTS
LIVINGSTON WIND ENERGY SURVEY - SERIES 2
March, April, May 1979

Site	Month	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watts/m^{-2})
S2A County Landfill				
	March 1979	14.9	13.0	334.1
	April 1979	16.0	13.9	376.2
	Mar-Apr	15.5	13.5	356.2
S2B Meyer Ranch				
	March 1979	10.7	9.3	151.0
	April 1979	12.2	10.6	169.3
	Mar-Apr.	11.5	10.0	161.4
S2C Hillman Ranch				
	April 1979	12.9	11.2	153.9
	May 1979	12.6	11.0	171.9
	Apr.-May	12.7	11.0	164.3

Table 10

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 3 S3A - Livingston West May, June, July 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
May	3.9	26.2	26.4	16.1	18.3	7.8	1.4	100.0	13.7	235.8
June	3.0	30.1	31.4	20.2	10.3	3.9	1.1	100.0	12.1	163.1
July	3.5	37.1	36.2	14.8	7.4	.8	.2	100.0	10.4	96.1

Table 11

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 3 S3B - Mcguire Hill June 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
June	1.7	23.4	29.0	21.7	16.9	6.2	1.0	100	13.8	217.5

Table 12

PERCENTAGE FREQUENCY OF WIND SPEED

Livingston WES - Series 3 | S3C - Brittan Ranch | May, June, July 1979

Month	Speed - mph 0-3	4-7	8-12	13-18	19-24	25-31	32+	Percent	Mean Wind Speed (mph)	Available Power (watts/m^2)
May	7.7	31.9	22.6	13.5	11.8	8.3	4.1	100	12.9	247.3
June	3.9	37.4	25.9	7.0	15.5	6.7	3.6	100	12.7	230.6
July	4.4	38.7	28.3	16.9	9.4	1.8	0.6	100	10.9	122.3

Table 13

SUMMARY OF RESULTS
LIVINGSTON WIND ENERGY SURVEY - SERIES 3
MAY, JUNE, JULY 1979

Site	Month	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watts/m^2)
S3A				
Livingston West				
	May 1979	13.7		235.8
	June 1979	12.1		163.1
	July 1979	10.4		96.1
	May-July	12.1		165.0
S3B				
McGuire Hill				
	June 1979	13.8		217.5
S3C				
Brittan Ranch				
	May 1979	12.9		247.3
	June 1979	12.7		230.6
	July 1979	10.9		122.3
	May-July	12.2		200.1

Table 14

MISSION FIELD FAA - FSS WIND SPEED
Livingston WES - Series 1
December 1978, January, February 1979

Month	Mean Wind Speed, Ws (knots)	(mph)	Available Power (watts/m^{-2})
(1978-1979)			
Dec.	18.1	20.8	691.5
Jan.	14.4	16.6	389.5
Feb.	15.4	17.7	462.0
Jan. - Feb	14.9	17.1	424.2
Dec., Jan., Feb.	16.2	18.6	520.8
(1/72 - 12/76)			
Dec.	17.4	19.9	587.6
Jan.	17.9	20.5	663.6
Feb.	17.4	20.0	565.6
Jan. - Feb	17.6	20.2	614.2
Dec., Jan., Feb.	17.5	20.1	601.2

Table 15

MISSION FIELD FAA - FSS WIND SPEED
Livingston WES - Series 2
March, April, May 1979

Month	Mean Wind Speed, Ws (knots)	Mean Wind Speed, Ws (mph)	Available Power (watts/m^{-2})
(1979)			
March	13.3	15.3	271.1
April	12.3	14.1	216.0
May	12.1	13.9	232.6
Apr-May	12.2	14.0	224.3
(1/72-12/76)			
March	13.8	15.9	327.3
April	12.0	13.8	212.8
May	11.1	12.8	177.5
Mar-Apr	12.9	14.9	270.1
Apr-May	12.1	13.9	222.7

Table 16

MISSION FIELD FAA-FSS WIND SPEED
LIVINGSTON WES-SERIES 3
MAY, JUNE, JULY 1979

Month	Mean Wind Speed, Ws (knots)	Mean Wind Speed, Ws (mph)	Available Power (watts/m^{-2})
(1979)			
May	12.1	13.9	232.6
June	11.0	12.7	160.6
July	10.4	12.0	146.0
May-July	11.2	12.9	179.7
(1/72-12/76)			
May	11.1	12.8	177.5
June	11.1	12.8	176.7
July	9.4	10.8	116.9
May-July	10.5	12.1	157.0

Table 17

WIND SPEED CORRELATION FACTORS
Livingston WES - Series 1

Site	Period	Mean Wind Speed (knots)	Mean Wind Speed (mph)	Correlation Factor - CF*
FSS	Dec, Jan, Feb	16.2	18.6	1.00
FSS	Jan, Feb	14.9	17.1	1.00
S1A	Dec, Jan, Feb	15.6	17.9	0.96
S1B	Jan, Feb	9.7	11.2	0.65
S1C	Jan, Feb	14.5	16.7	0.97

* $CF = W_s$ Site/ W_s FSS

Table 18

WIND SPEED CORRELATION FACTORS
Livingston WES - Series 2

Site	Period	Mean Wind Speed (knots)	Mean Wind Speed (mph)	Correlation Factor - CF*
FSS	Mar-Apr	12.8	14.7	1.00
FSS	Apr-May	12.2	14.0	1.00
S2A	Mar-Apr	13.5	15.5	1.05
S2B	Mar-Apr	10.0	11.5	0.78
S2C	Apr-May	11.0	12.7	0.90

* $CF = W_s$ Site/ W_s FSS

Table 19

WIND SPEED CORRELATION FACTORS

Livingston WES - Series 3

Site	Period	Mean Wind Speed (knots)	Mean Wind Speed (mph)	Correlation Factor - CF*
FSS	May, June, July	11.2	12.8	1.00
S3A	May, June, July	10.5	12.1	0.93
S3B	June	12.0	13.8	1.05
S3C	May, June, July	10.6	12.2	0.98

* $CF = W_s$ Site/ W_s FSS

Table 20

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | FAA-FSS Mission Field | Annual 1/72-12/76

Month	Speed - knots 0-3	4-9	10-15	16-21	22-30	31+	Mean Wind Speed (knots)	(mph)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	17.9	20.6	659.6
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	17.4	20.0	563.8
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	13.9	16.0	331.4
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	12.0	13.8	212.8
May	11.0	34.2	36.2	15.2	3.3	0.1	11.1	12.8	177.5
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	11.1	12.8	176.2
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	9.4	10.8	115.8
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	10.2	11.7	140.7
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	10.2	11.7	153.8
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	11.6	13.3	232.0
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	14.4	16.6	393.6
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	17.4	20.0	583.6
Annual	9.0	29.0	32.1	18.4	8.8	2.6	13.1	15.1	310.8

Table 21

WIND SPEED FORECAST - SERIES 1 SITES
LIVINGSTON WIND ENERGY SURVEY

	Speed - mph			
Month	FSS	S1A	S1B	S1C
Jan	20.6	19.8	13.7	20.0
Feb	20.0	19.2	13.2	19.4
Mar	16.0	15.4	10.7	15.6
Apr	13.8	13.3	9.2	13.5
May	12.8	12.3	8.5	12.4
Jun	12.8	12.3	8.5	12.4
July	10.8	10.4	7.1	10.5
Aug	11.7	10.9	7.8	11.4
Sept	11.7	11.3	7.8	11.5
Oct	13.3	13.3	9.2	13.5
Nov	16.6	16.1	11.0	16.1
Dec	20.0	19.2	13.3	19.4
Annual	15.1	14.5	10.0	14.6

Table 22

WIND SPEED FORECAST - SERIES 2 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Speed - mph			
	FSS	S2A	S2B	S2C
Jan	20.6	22.7	16.4	19.1
Feb	20.0	22.0	16.0	18.6
Mar	16.0	17.6	12.8	15.0
Apr	13.8	15.2	11.0	12.9
May	12.8	14.0	10.2	11.8
Jun	12.8	14.0	10.2	11.8
Jul	10.8	11.9	8.6	10.0
Aug	11.7	12.5	9.1	10.6
Sep	11.7	12.9	9.3	10.9
Oct	13.3	15.3	11.2	12.9
Nov	16.6	18.4	13.3	15.5
Dec	20.0	22.0	16.0	18.6
Annual	15.1	16.6	12.0	13.9

Table 23

WIND SPEED FORECAST - SERIES 3 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Speed - mph			
	FSS	S3A	S3B	S3C
Jan	20.6	19.2	21.6	20.0
Feb	20.0	18.6	20.9	19.4
Mar	16.0	15.0	16.8	15.6
Apr	13.8	12.9	14.5	13.5
May	12.8	11.9	13.5	12.4
Jun	12.8	12.0	13.5	12.5
July	10.8	10.0	11.4	10.6
Aug	11.7	10.6	12.0	11.0
Sept	11.7	10.9	12.3	11.4
Oct	13.3	12.9	14.6	13.6
Nov	16.6	15.5	17.5	16.3
Dec	20.0	18.6	20.9	19.4
Annual	15.1	13.9	15.8	14.6

Table 24

AVAILABLE WIND POWER FORECAST - SERIES 1 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Available Power - watts/m^2*			
	FSS	S1A	S1B	S1C
Jan	659.6	589.2	195.1	610.7
Feb	563.8	503.6	165.8	520.8
Mar	331.4	296.1	97.5	309.4
Apr	212.8	190.1	62.6	197.5
May	177.5	158.6	52.2	167.5
Jun	176.2	159.4	52.5	163.5
Jul	115.8	105.4	34.7	108.3
Aug	140.7	125.7	43.0	134.4
Sept	153.8	137.4	47.2	147.4
Oct	232.0	207.2	68.2	213.4
Nov	393.6	351.6	114.1	357.2
Dec	583.6	521.4	172.8	540.9
Annual	310.8	277.6	91.4	286.8

* $1.0m^2 = 10.76$ ft.^{2}

Table 25

AVAILABLE WIND POWER FORECAST - SERIES 2 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Available Power - watts/m^2*			
	FSS	S2A	S2B	S2C
Jan	659.6	879.7	337.7	533.3
Feb	563.8	752.2	288.7	455.9
Mar	331.4	442.0	169.7	267.9
Apr	212.8	283.7	109.0	171.9
May	177.5	236.6	90.9	143.4
Jun	176.2	234.8	90.2	143.2
Jul	115.9	154.2	59.3	93.4
Aug	140.7	187.5	72.0	113.6
Sept	153.8	205.0	78.7	124.2
Oct	232.0	309.3	118.8	187.5
Nov	393.6	524.9	201.5	318.2
Dec	583.6	778.5	298.8	471.9
Annual	310.8	414.4	159.1	251.2

* 1.0 m^2 = 10.76 $ft.^2$

Table 26

AVAILABLE WIND POWER FORECAST - SERIES 3 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Available Power - watts/m^2*			
	FSS	S3A	S3B	S3C
Jan	659.6	535.4	764.7	613.0
Feb	563.8	457.0	654.0	524.0
Mar	331.4	268.3	384.7	308.0
Apr	212.8	172.0	247.1	197.8
May	177.5	143.4	206.1	165.0
June	176.2	144.2	207.2	165.9
July	115.8	95.3	137.0	109.7
Aug	140.7	113.6	163.3	130.8
Sept	153.8	124.2	178.5	142.9
Oct	232.0	187.5	269.3	215.6
Nov	393.6	318.8	456.6	365.8
Dec	583.6	473.3	676.9	542.4
Annual	310.8	251.7	360.6	288.9

* 1.0 m^2 = 10.76 $ft.^2$

Table 27

POTENTIAL WIND ENERGY FORECAST - SERIES 1 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Available Energy - kwhr/m^2*			
	FSS	S1A	S1B	S1C
Jan	290.5	259.3	86.1	269.0
Feb	224.9	200.1	66.7	207.7
Mar	146.3	131.3	43.0	136.7
Apr	90.4	80.7	28.0	83.9
May	78.5	69.9	22.6	74.2
Jun	75.3	67.8	22.6	71.0
Jul	50.6	46.3	15.1	47.3
Aug	62.4	56.0	19.4	59.2
Sept	65.6	59.2	20.4	63.5
Oct	102.2	91.5	30.1	83.9
Nov	167.9	149.6	50.6	152.8
Dec	257.2	229.2	76.4	238.9
Annual	1612.9	1440.8	474.5	1489.2

* 1.0 m^2 = 10.76 ft^2

Table 28

POTENTIAL WIND ENERGY FORECAST - SERIES 2 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Available Energy - kwhr/m^2*			
	FSS	S2A	S2B	S2C
Jan	290.5	387.4	148.5	238.1
Feb	224.9	300.2	115.1	181.8
Mar	146.3	194.8	75.3	118.4
Apr	90.4	121.6	46.3	73.2
May	78.5	104.4	39.8	63.5
Jun	75.3	100.1	38.7	61.3
Jul	50.6	67.8	25.8	42.0
Aug	62.4	82.9	32.3	50.6
Sep	65.6	87.2	33.4	52.7
Oct	102.2	136.7	52.7	82.9
Nov	167.9	223.8	86.1	135.6
Dec	257.2	343.2	132.3	207.7
Annual	1612.9	2150.9	826.4	1304.1

* 1.0 m^2 = 10.76 ft^2

Table 29

POTENTIAL WIND ENERGY FORECAST - SERIES 3 SITES
LIVINGSTON WIND ENERGY SURVEY

Month	Available Energy - kwhr/m^2*			
	FSS	S3A	S3B	S3C
Jan	290.5	236.1	337.1	270.3
Feb	224.9	182.0	260.4	208.7
Mar	146.3	118.3	169.6	135.8
Apr	90.4	73.4	105.4	84.4
May	78.5	63.2	90.9	72.7
June	75.3	61.5	88.4	70.8
July	50.6	42.0	60.4	48.4
Aug	62.4	50.1	72.0	57.7
Sept	65.6	53.0	76.2	61.0
Oct	102.2	82.7	118.7	95.1
Nov	167.9	136.0	194.8	156.1
Dec	257.2	208.7	298.4	239.1
Annual	1612.9	1303.0	1866.8	1495.6

* 1.0 m^2 = 10.76 ft^2

APPENDIX A

TABLE OF CONTENTS

Mission Field FAA-FSS Percentage Frequency of
Wind Direction and Speed

	Page
December, 1978	A-1
January, 1979	A-2
February, 1979	A-3
March 1979	A-4
April 1979	A-5
May 1979	A-6
June 1979	A-7
July 1979	A-8
January 1972-1976	A-9
February 1972-1976	A-10
March 1972-1976	A-11
April 1972-1976	A-12
May 1972-1976	A-13
June 1972-1976	A-14
July 1972-1976	A-15
August 1972-1976	A-16
September 1972-1976	A-17
October 1972-1976	A-18
November 1972-1976	A-19
December 1972-1976	A-20
Annual 1972-1976	A-21

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	December	1978	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N	1.2	3.4	1.6				6.3	7.5	50.8
NE		0.2					0.2	7.0	23.4
E		1.6		1.8	0.8		4.3	15.5	440.6
SE			0.2				0.2	13.0	149.8
S				0.2			0.2	19.0	467.8
SW	0.6	2.2	7.3	10.5	10.3	12.6	43.5	22.7	1087.1
W	0.2	5.5	7.5	10.7	6.5	0.8	31.0	17.3	525.7
NW	0.6	5.3	3.8	2.6	1.0		13.6	12.0	233.8
Percent	3.4	18.2	20.4	25.9	18.6	13.4	100.0		

Mean Wind Speed, W_s = 18.1 knots, 20.8 mph

Mean Available Power, Wm^{-2} = 691.5 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	January	1979	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		4.4	1.8	0.8	0.2		7.2	10.4	139.0
NE		0.6	0.2				0.8	8.5	55.0
E		4.8	5.0	4.6	1.4		15.8	14.1	303.2
SE		1.2	0.2				1.4	7.9	41.5
S				0.2			0.2	19.0	467.8
SW		1.0	3.6	8.2	9.9	2.5	25.2	21.9	894.9
W		7.6	9.5	9.5	2.4		29.0	14.5	313.5
NW		7.0	4.6	1.0			12.6	10.1	104.8
Percent	7.8	26.6	24.9	24.3	13.9	2.5			

Mean Wind Speed, W_s = 14.4 knots, 16.6 mph

Mean Available Power, Wm^{-2} = 389.5 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	February	1979	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		1.1	0.7	0.2			2.1	9.8	106.7
NE		0.5					0.5	7.0	23.4
E		7.7	5.0	0.7	1.4	0.7	15.5	12.4	296.6
SE		1.1					1.1	7.0	23.4
S		0.7					0.7	7.0	23.4
SW		2.7	12.1	15.9	10.0	5.5	46.2	19.9	742.4
W		4.6	11.2	4.8	1.8		22.3	14.2	283.2
NW		4.8	1.8	0.7			7.3	9.6	97.2
Percent	4.3	23.2	30.8	22.3	13.2	6.2	100.0		

Mean Wind Speed, W_s = 15.4 knots, 17.7 mph

Mean Available Power, Wm^{-2} = 462 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	March	1979	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N	0.2	2.6	0.8				3.6	8.1	50.2
NE		2.4	1.0				3.4	8.8	60.6
E	0.2	8.7	14.4	5.1	0.2		28.5	12.3	175.5
SE		0.6		0.2			0.8	10.0	134.5
S		0.8	0.2	0.2	0.2		1.4	12.4	282.9
SW	0.2	3.2	11.1	10.3	4.0	0.6	29.6	16.5	438.3
W		7.5	8.7	4.7	1.8	0.6	23.3	13.8	313.4
NW	2.2	4.0	2.2	0.8			7.1	10.0	112.3
Percent	2.8	30.0	38.5	21.3	6.3	1.2	100		

Mean Wind Speed, W_s = 13.3 knots, 15.3 mph

Mean Available Power, Wm^{-2} = 271.1 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	April Month	1979 Year	16/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		3.3	1.7	0.2			5.2	9.4	81.8
NE		0.8	0.4		0.2		1.4	11.5	237.5
E		2.9	7.4	4.5	0.8		15.7	14.2	273.7
SE		1.0	0.2				1.2	8.0	44.5
S		0.4	0.2				0.6	9.0	65.5
SW		6.0	14.0	7.2	1.2	0.4	26.9	15.1	298.3
W		9.3	15.7	5.8	2.1	0.2	33.1	13.3	253.6
NW	0.5	6.4	4.8	0.2			11.4	9.7	84.4
Percent	4.5	30.2	44.4	15.9	4.3	0.6	100		

Mean Wind Speed, W_s = 12.3 knots, 17.7 mph

Mean Available Power, Wm^{-2} = 216.0 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	May	1979	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N	0.2	3.2	1.8				5.2	8.9	66.3
NE	0.2	1.4	0.2				1.8	7.1	34.9
E		6.8	6.0	8.2	3.0		2.4	15.0	362.6
SE	0.2	3.4					3.6	6.7	22.1
S		1.0			0.2		1.2	10.3	231.0
SW		3.2	6.8	3.4	1.0	0.4	14.8	14.5	327.5
W	0.2	7.2	14.0	6.8	1.4	0.4	30.0	13.7	270.6
NW	.4/5.8	9.6	3.4	0.2			13.6	8.5	60.9
Percent	7.0	35.8	32.2	18.6	5.6	0.8	100		

Mean Wind Speed, W_s = 12.1 knots, 13.9 mph

Mean Available Power, Wm^{-2} = 232 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	June	1979	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		5.5	0.8	0.2	0.2		6.7	8.7	88.9
NE		2.9	0.2				3.1	7.4	31.6
E		5.9	5.5	3.7	0.4		15.5	12.5	206.5
SE		1.6	0.4	0.6			2.7	10.3	140.0
S		1.4	0.4				1.8	8.3	51.5
SW		7.2	11.7	5.5	1.2		25.6	13.2	235.1
W		8.2	14.9	3.3	0.2	0.2	26.8	12.1	174.2
NW		7.0	3.1	0.8			10.8	9.7	92.8
Percent	7.0	39.7	37.0	14.1	2.0	0.2	100.0	11.0	160.6

Mean Wind Speed, W_s = 11.0 knots, 12.7 mph

Mean Available Power, Wm^{-2} = 160.6 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	July	1979	16/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		7.2	1.4				8.8	8.4	71.8
NE		3.2	1.6	0.2	0.2		5.2	10.1	127.3
E		6.4	13.8	9.8	0.6		30.7	13.9	246.4
SE		1.6	1.2	0.6			3.4	11.2	146.4
S		0.6			0.2		0.8	11.9	334.8
SW		4.2	4.8	1.2	0.2	0.2	10.6	11.9	196.2
W		9.8	7.2	1.6	0.2		18.8	10.5	122.9
NW		10.0	1.6	0.2			11.8	8.0	48.1
Percent	9.8	43.1	31.7	13.6	1.6	0.2	100.0		

Mean Wind Speed, W_s = 10.4 knots, 12.0 mph

Mean Available Power, Wm^{-2} = 146.0 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	January	1/72-12/76	24/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		1.8	1.0	0.1			2.9	9.5	82.3
NE		0.2	0.2	0.1			0.5	11.8	162.8
E		2.7	2.9	3.0	0.7	0.1	9.4	14.4	320.5
SE		0.2					0.2	7.0	23.4
S		0.4	0.1				0.5	8.2	48.7
SW		2.9	8.2	13.1	17.1	10.6	51.9	22.5	1017.6
W		5.7	8.2	6.1	2.1	0.7	22.8	14.9	370.4
NW		4.3	3.8	0.6	0.1		8.8	9.2	105.6
Percent	2.8	18.2	24.3	23.0	20.0	11.7	100.0		

Mean Wind Speed, W_s = 17.9 knots, 20.47 mph

Mean Available Power, Wm^{-2} = 663.6 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	February	1/72-12/76	24/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		2.4	1.6	0.2			4.3	9.6	90.6
NE		0.4	0.1				0.5	8.2	48.7
E		2.0	3.4	3.4	0.9		9.7	15.1	339.1
SE		0.3					0.3	7.0	23.4
S		0.2					0.2	7.0	23.4
SW		1.6	10.0	17.0	16.6	5.4	50.6	21.3	842.4
W		3.7	9.0	7.9	2.5	0.3	23.3	15.8	385.1
NW		4.3	3.1	0.7	0.1		8.2		
Percent	2.8	14.9	27.2	29.3	20.1	5.7	100.0		

Mean Wind Speed, W_s = 17.4 knots, 20.01 mph

Mean Available Power, Wm^{-2} = 565.6 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	March Month	1972-1976 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		1.7	1.0	0.4	0.1		3.1	11.3	162.5
NE		0.6	0.02	0.02			0.6	8.1	44.0
E		3.4	5.3	0.2	0.2		11.0	9.3	111.0
SE		1.0	0.1				1.1	7.5	34.9
S		0.7	0.1	0.02			0.8	8.2	50.9
SW		4.1	12.6	12.7	7.0	1.9	38.2	17.8	551.2
W		6.5	11.9	7.2	1.7	0.1	27.5	14.0	279.4
NW		5.0	4.2	1.3	0.3		10.8	11.3	160.7
Percent	6.9	23.0	35.3	23.6	9.3	2.0	100.		

Mean Wind Speed, W_s = 13.9 knots, 16 mph

Mean Available Power, Wm^{-2} = 331.4 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	April Month	1972-1976 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		3.6	1.0	0.2			4.6	9.1	71.2
NE		0.7	0.3	0.1			1.1	9.7	98.3
E		4.4	9.0	4.7	1.3			14.0	273.2
SE		1.6	0.5				2.1	8.4	53.5
S		0.8	0.1	1.0			1.0	8.8	80.5
SW		5.4	12.8	7.3	2.4	0.2	28.1	14.7	318.6
W		7.4	10.4	4.4	1.0		23.2	12.8	218.1
NW		6.4	4.8	0.9	0.2		12.3	10.5	125.5
Percent	8.3	30.2	39.0	17.5	4.8	0.2	100		

Mean Wind Speed, W_s = 12 knots, 13.8 mph

Mean Available Power, Wm^{-2} = 212.8 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	May	1972-1976	24/day
		Month	Year	obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		3.8	0.7	0.1			4.6	8.2	52.3
NE		1.0	0.4	0.1	0.1		1.6	10.5	160.6
E		4.9	8.9	5.2	0.8		19.8	13.6	247.3
SE		2.0	0.7	0.1			2.8	8.9	70.9
S		1.1	0.2				1.3	7.9	42.8
SW		5.0	10.9	5.4	1.3	0.1	22.7	14.0	270.9
W		8.9	11.4	3.8	1.0		25.1	12.3	197.7
NW		7.5	3.1	0.5	0.1		11.2	9.4	90.0
Percent	11.0	34.2	36.2	15.2	3.3	0.1	100		

Mean Wind Speed, W_s = 11.1 knots, 12.8 mph

Mean Available Power, Wm^{-2} = 177.5 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	June Month	1972-76 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		4.3	0.7	0.1			5.1	8.1	49.5
NE		1.3	0.4	0.1			1.8	9.0	76.2
E		4.9	7.1	3.7	0.4		16.8	12.4	203.4
SE		1.8	0.8	0.1			2.6	9.6	80.3
S		0.8	0.2	0.1			1.0	10.1	95.5
SW		5.4	11.8	5.3	1.3	0.1	23.7	13.8	258.9
W		9.4	12.7	5.5	0.8	0.1	28.4	12.6	205.0
NW		6.9	2.5	0.4	0.1		9.9	9.2	85.9
Percent	10.6	34.7	36.1	15.3	3.2	0.1	100.0		

Mean Wind Speed, W_s = 11.1 knots, 12.8 mph

Mean Available Power, Wm^{-2} = 176.7 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	July Month	1972-76 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		6.1	1.1	0.1			7.3	8.1	48.5
NE		1.7	0.9	0.2			2.8	9.8	95.8
E		7.2	11.2	4.5	0.8		23.7	12.8	209.6
SE		2.9	1.0	0.1			4.0	8.8	66.1
S		1.5	0.3	0.1			1.9	8.1	54.4
SW		6.0	6.1	1.7	0.2	0.1	14.1	11.5	165.0
W		9.2	6.9	1.7	0.2	0.1	18.0	10.7	133.9
NW		9.6	2.6	0.3	0.1		12.7	8.6	69.4
Percent	15.5	44.2	30.1	8.6	1.4	0.2	100.0		

Mean Wind Speed, W_s = 9.4 knots, 10.8 mph

Mean Available Power, Wm^{-2} = 116.9 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	August Month	1972-76 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		5.4	0.9	0.1			6.3	8.2	48.9
NE		2.1	0.6	0.3	0.1		3.1	10.0	131.1
E		6.4	8.3	3.5	0.8		19.0	12.7	212.9
SE		2.5	0.8	0.1	0.1		3.4	9.2	84.9
S		1.6	0.3	0.1			2.0	8.5	64.6
SW		5.5	8.7	4.4	1.2	0.1	19.9	13.6	263.2
W		8.0	8.4	2.2	0.3		18.9	11.4	151.1
NW		9.1	2.3	0.3	0.1	0.1	11.7	8.7	74.6
Percent	25.7	40.4	30.2	11.1	2.5	0.2	100.0		

Mean Wind Speed, W_s = 9.9 knots, 11.4 mph

Mean Available Power, Wm^{-2} = 141.8 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	September Month	1972-76 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		6.2	1.4	0.1			7.6	8.2	49.8
NE		1.3	0.4	0.1			1.8	9.0	76.2
E		5.5	7.9	3.0	0.4		16.9	12.4	190.7
SE		2.1	0.6				2.7	8.3	51.5
S		1.1	0.1	0.1	0.1		1.3	9.7	146.9
SW		5.7	9.0	4.3	1.8	0.2	21.2	13.8	293.6
W		8.4	7.8	3.2	1.0		20.4	12.1	202.5
NW		10.5	3.3	0.4	0.1		14.3	8.8	69.3
Percent	13.9	40.9	30.6	11.1	3.3	0.2	100.0		

Mean Wind Speed, W_s = 10.2 knots, 11.7 mph

Mean Available Power, Wm^{-2} = 153.8 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	October Month	1972-1976 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		4.0	1.4	0.1			5.4	8.9	64.8
NE		1.0	0.2	0.05			1.2	8.8	64.0
E		4.4	5.3	2.7	0.6		13.0	12.8	224.7
SE		1.4	0.1	0.1			1.6	8.1	59.1
S		0.6	0.05	0.05	0.05		0.7	10.2	154.8
SW		5.1	12.8	10.1	4.8	0.3	33.0	16.1	409.8
W		7.5	10.1	4.9	0.9		23.4	12.9	218.9
NW		7.3	4.2	0.5	0.1		12.1	9.7	95.9
Percent	9.7	31.2	34.1	18.3	6.4	0.3	100.0		

Mean Wind Speed, W_s = 12.1 knots, 13.9 mph

Mean Available Power, Wm^{-2} = 232.0 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	November Month	1972-1976 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N		2.1	0.6	0.1			2.8	8.7	66.4
NE		0.5		0.1			0.6	7.4	58.5
E		5.4	6.0	2.1	0.2		13.7	11.8	165.1
SE		0.9	0.2				1.1	8.1	46.4
S		0.3	0.1	0.1			0.5	10.6	137.6
SW		3.0	13.3	13.2	11.0	3.5	44.0	19.3	682.3
W		5.4	9.1	5.4	1.5	0.1	21.5	14.0	295.7
NW		5.0	3.2	0.4	0.1		8.6	10.1	105.9
Percent	7.2	22.7	32.5	21.4	12.7	3.5	100.0		

Mean Wind Speed, W_s = 14.5 knots, 16.7 mph

Mean Available Power, Wm^{-2} = 393.6 watts/m^2

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES	FAA-FSS Mission Field	December Month	1/72-12/76 Year	24/day obs.

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N	0.4	1.4	0.8	0.2			2.9	8.6	85.0
NE	0.6	0.2					0.9	2.9	5.6
E	0.3	1.4	2.8	1.2	0.1		5.9	12.2	113.3
SE	0.1	0.3					0.4	5.8	17.7
S	0.4	0.2					0.6	3.7	8.2
SW	0.6	1.8	13.6	17.6	16.1	7.5	57.7	20.7	823.4
W	0.3	4.8	8.7	6.9	2.6	0.2	23.7	14.9	354.0
NW	0.2	3.5	3.3	0.8	0.1	0.0	7.9	5.9	79.5
Percent	4.0	13.5				7.7	100.0		

Mean Wind Speed, W_s = 17.4 knots, 19.9 mph

Mean Available Power, Wm^{-2} = 587.6 watts/m^2,

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED

Livingston - WES | FAA-FSS Mission Field | Annual | 1/72-12/76

Direction	Speed - Knots 0-3	4-9	10-15	16-21	22-30	31+	Percent	Mean Wind Speed	Available Power (watts/m^2)
N	0.1	3.6	1.0	0.1			4.9	8.2	57.3
NE	1.4	0.9	0.3	0.1			2.8	5.3	40.6
E	1.0	4.4	6.6	3.3	0.6		15.7	12.6	216.4
SE	0.7	1.4	0.4				2.6	6.3	35.8
S	0.6	0.8	0.1				1.6	5.1	21.3
SW	1.0	4.3	10.9	9.4	6.7	2.5	34.8	17.5	581.1
W	0.7	7.1	9.6	4.6	1.3	0.1	23.8	12.6	236.6
NW	0.7	6.7	3.4	0.6	0.1		11.5	9.3	93.4
Calm	2.1								
Percent	8.4	29.3	32.4	18.5	8.8	2.6			

Mean Wind Speed, W_s = 13.1 knots, 15.1 mph

Mean Available Power, Wm^{-2} = 311.8 watts/m^2

APPENDIX B

TABLE OF CONTENTS

LIV-WES Long Term Forecast
Percentage Frequency of Wind Speed by Month

Series 1

S1A - Harvatt's Flat B-1
S2B - Koffee Kup Ranch B-2
S2C - Hunter's Hot Springs B-3

Series 2

S2A - County Landfill B-4
S2B - Meyers Ranch B-5
S2C - Hillman Ranch B-6

Series 3

S3A - Livingston West B-7
S3B - McGuire Hill B-8
S3C - Brittan Ranch B-9

PERCENTAGE FREQUENCY OF WIND
SPEED BY MONTH

Livingston - WES | S1A - Harvatt's Flat | Long-Term Forecast

Speed - mph

Month	$\overline{2.2}$	$\overline{7.7}$	$\overline{14.4}$	$\overline{21.0}$	$\overline{29.3}$	$\overline{35.4+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	19.8	17.2	589.2
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	19.2	16.7	503.6
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	15.4	13.4	296.1
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	13.3	11.6	190.1
May	11.0	34.2	36.2	15.2	3.3	0.1	12.3	10.7	158.6
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	12.3	10.7	159.4
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	10.4	9.0	105.4
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	10.9	9.5	125.7
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	11.3	9.8	137.4
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	13.3	11.6	207.2
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	16.1	14.0	351.6
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	19.2	16.7	521.4
Annual	9.0	29.0	32.1	18.4	8.8	2.6	14.5	12.6	277.6

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S1B - Koffee Kup Ranch | Long-Term Forecast

Speed - mph

Month	$\overline{1.5}$	$\overline{5.3}$	$\overline{9.9}$	$\overline{14.5}$	$\overline{20.3}$	$\overline{24.5+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	13.7	11.9	195.1
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	13.2	11.5	165.8
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	10.7	9.3	97.5
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	9.2	8.0	62.6
May	11.0	34.2	36.2	15.2	3.3	0.1	8.5	7.4	52.2
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	8.5	7.4	52.2
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	7.1	6.2	34.7
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	7.8	6.8	43.0
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	7.8	6.8	47.2
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	9.2	8.0	68.2
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	11.0	9.6	114.1
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	13.3	11.6	172.8
Annual	9.0	29.0	32.1	18.4	8.8	2.6	10.0	8.7	91.4

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S1C - Hunter's Hot Springs | Long-Term Forecast

Speed - mph

Month	$\overline{2.2}$	$\overline{7.8}$	$\overline{14.5}$	$\overline{21.3}$	$\overline{29.7}$	$\overline{35.8+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	20.0	17.4	610.7
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	19.4	16.9	520.8
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	15.6	13.6	309.4
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	13.5	11.7	197.5
May	11.0	34.2	36.2	15.2	3.3	0.1	12.4	10.8	167.5
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	12.4	10.8	163.5
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	10.5	9.1	108.3
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	11.4	9.9	134.4
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	11.5	10.0	147.4
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	13.5	11.7	213.4
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	16.1	14.0	357.2
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	19.4	16.9	540.9
Annual	9.0	29.0	32.1	18.4	8.8	2.6	14.6	12.7	286.8

Mean Wind Speed, 12.7 knots, 14.6 mph

Mean Available Power, 286.8 watts/m^2

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S2A - County Landfill | Long-term Forecast

Month	Speed - mph $\overline{2.5}$	$\overline{8.9}$	$\overline{16.5}$	$\overline{24.0}$	$\overline{33.6}$	$\overline{40.5+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	22.7	19.7	879.7
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	22.0	19.1	752.2
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	17.6	15.3	442.0
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	15.2	13.2	283.7
May	11.0	34.2	36.2	15.2	3.3	0.1	14.0	12.2	236.6
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	14.0	12.2	234.8
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	11.9	10.3	154.2
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	12.5	10.9	187.5
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	12.9	11.2	205.0
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	15.3	13.3	309.3
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	18.4	16.0	524.9
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	22.0	19.1	778.5
Annual	9.0	29.0	32.1	18.4	8.8	2.6	16.6	14.4	414.4

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S2B - Meyers Ranch | Long-term Forecast

Month	Speed - mph $\overline{1.8}$	$\overline{6.4}$	$\overline{12.0}$	$\overline{17.5}$	$\overline{24.4}$	$\overline{29.4+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	16.4	14.3	337.7
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	16.0	13.9	288.7
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	12.8	11.1	169.7
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	11.0	9.6	109.0
May	11.0	34.2	36.2	15.2	3.3	0.1	10.2	8.9	90.9
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	10.2	8.9	90.2
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	8.6	7.5	59.3
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	9.1	7.9	72.0
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	9.3	8.1	78.7
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	11.2	9.7	118.8
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	13.3	11.6	201.5
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	16.0	13.9	298.8
Annual	9.0	29.0	32.1	18.4	8.8	2.6	12.0	10.4	159.1

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S2C - Hillman Ranch | Long-Term Forecast

Month	Speed - mph $\overline{2.2}$	$\overline{7.5}$	$\overline{13.9}$	$\overline{20.4}$	$\overline{28.4}$	$\overline{34.3+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	19.1	16.6	533.3
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	18.6	16.2	455.9
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	15.0	13.0	267.9
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	12.9	11.2	171.9
May	11.0	34.2	36.2	15.2	3.3	0.1	11.8	10.3	143.4
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	11.8	10.3	143.2
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	10.0	8.7	93.4
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	10.6	9.2	113.6
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	10.9	9.5	124.2
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	12.9	11.2	187.5
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	15.5	13.5	318.2
Dec.	4.0	13.5	29.1	26.7	18.9	7.6	18.6	16.2	471.9
Annual	9.0	29.0	32.1	18.4	8.8	2.7	13.9	12.1	251.2

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S3A - Livingston Ranch | Long-Term Forecast

Speed - mph

Month	$\overline{2.2}$	$\overline{7.5}$	$\overline{13.9}$	$\overline{20.4}$	$\overline{28.4}$	$\overline{34.3+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	19.2	16.7	535.4
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	18.6	16.2	457.0
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	15.0	13.0	268.3
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	12.9	11.2	172.0
May	11.0	34.2	36.2	15.2	3.3	0.1	11.9	10.3	143.4
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	12.0	10.4	144.2
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	10.0	8.7	95.3
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	10.6	9.2	113.6
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	10.9	9.5	124.2
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	12.9	11.2	187.5
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	15.5	13.5	318.8
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	18.6	16.2	473.3
Annual	9.0	29.0	32.1	18.4	8.8	2.6	13.9	12.1	251.7

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S3B - McGuire Hill | Long-Term Forecast

Speed - mph

Month	2.2	7.5	13.9	20.4	28.4	34.3+	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	21.6	18.8	764.7
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	20.9	18.2	654.0
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	16.8	14.6	384.7
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	14.5	12.6	247.1
May	11.0	34.2	36.2	15.2	3.3	0.1	13.5	11.7	206.1
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	13.5	11.7	207.2
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	11.4	9.9	137.0
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	12.0	10.4	163.3
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	12.3	10.7	178.5
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	14.6	12.7	269.3
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	17.5	15.2	456.6
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	20.9	18.2	676.9
Annual	9.0	29.0	32.1	18.4	8.8	2.6	15.8	13.7	360.6

PERCENTAGE FREQUENCY OF WIND
MONTH VS SPEED

Livingston - WES | S3C - Brittan Ranch | Long-Term Forecast

Speed - mph

Month	$\overline{2.2}$	$\overline{7.9}$	$\overline{14.6}$	$\overline{21.3}$	$\overline{29.7}$	$\overline{35.9+}$	Mean Wind Speed (mph)	Mean Wind Speed (knots)	Available Power (watt/m^2)
Jan.	2.9	18.3	24.3	23.1	20.0	11.5	20.0	17.4	613.0
Feb.	2.8	14.9	27.2	29.3	20.1	5.7	19.4	16.9	524.0
Mar.	6.9	23.0	35.3	23.6	9.3	2.0	15.6	13.6	308.0
Apr.	8.3	30.2	39.0	17.5	4.8	0.2	13.5	11.7	197.8
May	11.0	34.2	36.2	15.2	3.3	0.1	12.4	10.8	165.0
Jun.	10.6	34.7	36.1	15.2	3.2	0.2	12.5	10.9	165.9
Jul.	15.5	44.2	30.1	8.6	1.4	0.2	10.6	9.2	109.7
Aug.	15.7	40.4	30.2	11.1	2.5	0.1	11.0	9.6	130.8
Sep.	13.9	40.9	30.6	11.1	3.3	0.2	11.4	9.9	142.9
Oct.	9.7	31.2	34.1	18.3	6.4	0.3	13.6	11.8	215.6
Nov.	7.2	22.7	32.5	21.4	12.7	3.5	16.3	14.2	365.8
Dec.	4.0	13.5	29.1	26.7	18.9	7.7	19.4	16.9	542.4
Annual	9.0	29.0	32.1	18.4	8.8	2.6	14.6	12.7	288.9

APPENDIX C

A Description of the Equipment Used In the Livingston Wind Energy Survey Project

The wind speed and direction instrumentation and recording system, NPI Model A11-132, was purchased from Natural Power Inc, New Boston, New Hampshire. The installation included a 40' telescoping tower erected to 10 m (32.8 ft) for instruments, which was guyed by 9 guy wires to 3 stakes driven into the surrounding ground. These instrument towers supported anemometer and wind direction heads. Installation required extending the sections, inserting cotter pin, and rotating the tube until it is locked. The bottom section of tubing is 16-gauge galvanized steel; all other sections are 18-gauge. Guy wire and ground ties were locally obtained. The instruments were mounted on an aluminum stub mast, which was bolted to the top of the tower.

The NPI Model A11 wind speed recording system uses the Model A70-108 Anemometer Head and Interface Electronics and provides switch-selected 0-to-50 and 0-to-100 mph wind speed scales. Sensing the frequency rather than the voltage of the anemometer head generator, they feature linear scales and are relatively unaffected by interfering signals or by wire runs of thousands of feet from the head to the recorder.

Specifications - NPI Model A11

Input Power	9 to 15 VDC, 15 to 40 MA
Input Connector	Screw Terminal.
Output Display	A96-200 Chart Paper 5", Two Pointer Indicators.
Controls	On-Off, Chart Advance. Chart Scale: 0-50; 0 to 100 mph.
Temperature	0° to 70° C.

The wind speed was sensed by a NPI A75-108 cup anemometer with transducer. A75-108 Anemometer heads, manufactured by Maximum Inc., are completely self-powered, featuring self-contained alternators. They offer the following advantages: Permanently lubricated bearings, rust-proof beryllium copper shafts, shatterproof Lexan rotating cups, no brushes or slip rings to wear out or become dirty, stainless steel mounting hardware. Cable runs of up to 500 feet, or over 2,000 feet using NPI interface electronics, will not cause loss of accuracy and/or loss of linear rpm/frequency relationship over wind speeds from 3 to 103 mph. Model A75-108 8-pole Anemometer Head is designed to interface with NPI recorders for improved lowend stability. Each Anemometer Head is supplied with 60 feet of 2-wire cable, a stub mast and mounting clamps. The cables are not suitable for underground installation.

Specifications - NPI Model A75-108 Anemometer Head

Cup Assembly	Lexan, Rotate at 1760 rpm in 100 mph wind three 2" dia. Cups of Conical Crossection
Cup Swept Diameter	7.5"
Starting Velocity	Below 3 mph
Weight	3.7 oz.
Stub Mast Diameter	0.505"
Warranty	Maximum, Inc.,5-year warranty

The wind direction was sensed by a NPI model A75-301 wind direction head transducer. This pick-up unit requires 12 vdc current, primarily for the light emitting drodes. It includes eight dry reed, magnetically operated, hermetically-sealed, nitrogen-filled switches which use only ½ watt total. Model A75-301 wind direction head transmits the direction information down the cable as a gray code suitable for NPI Model Interface Electronics. The Model A75-301 is supplied with 75 feet of 5-wire cable, stub mounting mast, and mast clamps.

Specifications - NPI Model A75-301 Wind Direction Head

Swept Diamter	9"
Free Wind Response	2 mph
Weight	2.6 oz.
Stub Mast Diameter	0.505" dia.max.
Warranty	Maximum, Inc., 5-year warranty

The wind data is recorded on a dual-channel Rustrack recorder. Input data is recorded at two-second intervals; the effective chart width is approximately 2¼ inches per channel. At the standard chart speed of 1 inch/hour, each recorder can accommodate a one-month supply of chart paper in a roll.

The NPI wind recording system was housed in an all weather, plastic housing. This in turn was enclosed in a 3/4" plywood wooden box with a padlock on it. The recorder was powered by a 12-volt marine battery which was housed in a separate polyethylene, all-weather housing.

15 copies of this public document were published at an estimated cost of $6.00 per copy, for a total cost of $90.00, which includes $90.00 for printing and $.00 for distribution.